State of California
California Regional Water Quality Control Board, Los Angeles Region

Peer Review – Staff Memorandum

Technical Memorandum #4:
Nitrogen Loads from Wastewater Flowing to Malibu Lagoon are a Significant Source of Impairment to Aquatic Life

By

Toni Callaway, P.G., Engineering Geologist

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Linda S. Adams
Cal/EPA Secretary

Arnold Schwarzenegger
Governor

Date: October 21, 2009

To: Rebecca Chou, Ph.D., P.E., Chief of Groundwater Permitting Unit
Wendy Phillips, PG, CHG, CEG, Chief of Groundwater Permitting and Landfill Section

From: Toni Callaway, P.G., Engineering Geologist, Groundwater Permitting Unit

Subject: **Peer Review Response to Comments - Technical Memorandum #4: Nitrogen Loads from Wastewater Flowing to Malibu Lagoon are a Significant Source of Impairment to Aquatic Life**

Attachments:

1. Comment dated September 5, 2009 from Dr. Robert Arnold of Arizona State University
2. Comments dated September 10, 2009 from Dr. Jörg Drewes of Colorado School of Mines
3. Comments dated September 12, 2009 from Dr. JoAnn Silverstein of the University of Colorado at Boulder

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To ensure that the proposed amendment to the *Basin Plan*[1] is based on sound science and engineering principles, the scientific elements of Technical Memorandum (Tech Memo) #4: *Nitrogen Loads from Wastewater Flowing to Malibu Lagoon are a Significant Source of Impairment to Aquatic Life,* draft dated August 5, 2009 (Tech Memo #4), were peer reviewed. This peer review was conducted in accordance with requirements and guidelines from the Cal/EPA Scientific Peer Review Program, Office of Research, Planning and Performance.

All three peer reviewers responded promptly and provided valuable comments. In summary, all three peer reviewers found that the basic approaches and methods used to calculate the nitrogen loading to Malibu Lagoon in Tech Memo #4 incorporated sound scientific and engineering principles.

Suggestions were made to clarify the assumptions made by staff. Staff responded to these suggestions and revised Tech Memo #4 as appropriate and noted that none of the changes materially altered the conclusion of Tech Memo #4. That is: On-site subsurface disposal systems (OWDSs) in the Malibu Civic Center area cumulatively release nitrogen to Malibu Lagoon at

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[1] Proposed amendment to the *Water Quality Control Plan for Coastal Watersheds of Los Angeles and Ventura Counties (Basin Plan)* to prohibit on-site subsurface disposal systems (OWDSs) in the Malibu Civic Center area.

rates that violated the total maximum daily limit (TMDL) adopted by the US Environmental Protection Agency in 2003 for the Malibu Lagoon (USEPA, 2003).

Comments have been summarized into three main issues and presented in *italics*, followed by staff's response. The main issues raised in the comments are: 1) Residential Loading - Is the 100 gallons per day per person (gpd/person) wastewater flow rate assumed in the Tech Memo for single-family homes realistic? 2) Commercial Loading - Are the flow rates estimated for un-permitted commercial properties in the Tech Memo accurate? and 3) TN/BOD Ratio - Is the TN/BOD Ratio of 0.20 in wastewater used in the Tech Memo an appropriate estimation for total nitrogen (TN) when biochemical oxygen demand (BOD_5) data is available while TN data is not available? Comments related to these issues are addressed in paragraphs 1 through 3 below:

1. ***Residential Loadings****: Comparing to the typical rate of wastewater generation per capital in the literature (40 to 90 gpd/person), the 100 gpd/person rate used in Tech Memo #4 for the Malibu Civic Center area may be too high.*

   Staff considers the residences in the Malibu Civic Center area luxury homes, because almost all the 392 residences in the area are large single family homes with more than 3.5 bath/bedrooms per house. Many studies have shown that luxury homes use more water than ordinary homes and therefore generate more wastewater. For example, Metcalf and Eddy (1991, Table 2-9, page 27) reported that the average water usage for luxury homes in residential areas was 75-150 gpd/person, while the water usage for the average home nationwide was 70 gpd/person. The higher than typical wastewater flow rate used in Tech Memo #4 is also supported by historical water use data of Malibu City. In 2008, the population of the Malibu City was 13,009 and the water consumption of the City was 2,200 million gallons for both commercial and residential usage. It has been estimated that approximately 54% of urban water usage is residential (Department of Water Resource in California) and that 50% of residential water usage is for irrigation (American Water Works Association). Assuming these percentages are applicable to the Malibu Civic Center area, the net per capita water consumption (excluding irrigation use) would be 125 gpd/person. Because the bulk of residential water consumption becomes wastewater at the end, the 100 gpd/person of wastewater flow rate used for the Malibu Civic Center area is a reasonable estimate. Tech Memo #4 has therefore not been modified in response to this comment.

2. ***Commercial Loading****: In Tech Memo #4, wastewater flow rates from small businesses were estimated using on-site population and business activity information. A few details or examples of the process by which wastewater flows were assigned might provide a feel for this work.*

A new column (category) has been added to Table 1 in Tech Memo #4 to characterize each commercial facility, including whether flow rate of the facility was estimated. New footnotes have also been added to Table 1 to better explain the data source for each facility. Of the 38 commercial facilities in the Malibu Civic Center area that discharge wastewater with OWDSs, the flow rates of 7 facilities were not available and had to be estimated. This constitutes 5.4% of the total commercial flow.

3. ***TN/BOD Ratio****: Staff assumed a constant fraction (0.20) of total nitrogen concentration to five-day biochemical oxygen demand (TN/BOD_5) to estimate nitrogen load of commercial sources where only BOD_5 measurements were available. More appropriate references should be used to provide the accurate representation of single source waste streams. TN/BOD ratios from single sources should be site-specific and highly depending on the types of dischargers (i.e. lower in restaurant effluents). If local data exist with which to make this distinction, they should be cited in the text. It is advisable that samples be taken to verify the TN:BOD ratio from specific dischargers with higher flow.*

BOD_5 is a measurement of the amount organic substances in wastewater. Because nitrogen in wastewater is mostly derived from organic substances (proteins), the concentration of total nitrogen generally increases with the increase of BOD_5. The 0.20 TN/BOD_5 ratio used in Tech Memo #4 is consistent with tables characterizing residential wastewater found in college textbooks, such as Metcalf and Eddy (1991) and Crites and Tchobanoglous (1998). Staff has added Table 4 which summarizes TN and BOD analytical data from 106 septic tank wastewater samples from large mixed usage commercial facilities located in the Malibu Civic Center area. The average TN/BOD_5 ratio for these samples was 20.4%, which is essentially the same as what was used in Tech Memo #4. The mixed use commercial properties include restaurants, but there are few stand-alone restaurant in the Malibu Civic Center area.

Staff responses to comments requiring minor clarification summarized in paragraphs A through H below:

A. Staff should provide more information regarding the OWDSs being used in the Malibu Civic Center area, such as a definition of "advanced" OWTS treatment. In the interest of defining the most significant sources of nitrogen load, the facilities that provide advanced treatment, the nature of the treatment provided, and typical BOD_5 and total nitrogen removal efficiencies might be added to the report. The credits between OWDSs and soil profile to the removal of nitrogen/BOD should be clarified.

"Advance OWTS treatment" is defined as more advanced than primary treatment, i.e. secondary and tertiary treatment with disinfection. The advanced systems in the Malibu

Civic Center area vary greatly, no two are alike, but a footnote (Footnote D) has been added to Table 1 to identify advanced OWTSs. As stated in Tech Memo #4, the Regional Board lacks site specific information for the hundreds of residential septic systems in the Malibu Civic Center area. When available, the effluent loads (nitrogen concentration) in Table 1 listed real "end-of-pipe" data.

In Table 3 of Tech Memo #4, credits for TN reduction in the soil profile are based on soil type (e.g. sandy loam), sufficient groundwater separation (e.g. 5 feet to 10 feet from bottom of leachfield to groundwater), and demonstrated unsaturated soil assimilative capacity. The high density of wastewater discharges in many of the commercial and residential areas of Malibu preclude adequate subsurface assimilative capacity. Available data indicates that site conditions in the coastal strips (high groundwater) and the highland residential area (fractured bedrock with the prevalent usage of seepage pits for disposal) do not warrant further reduction of nitrogen loads by soil treatment.

B. Because many calculations in the spreadsheet model were based on assumptions, a sensitivity analysis of the eventual nitrogen load estimates in response to the variation of key input parameters, such as flow rate, TN, and soil attenuation factor, is recommended.

Staff has conducted a sensitivity analysis to the spreadsheet model, but little impact was observed to the eventual nitrogen load estimates. Sensitivity analysis was made by changing the estimated flow rate and TN concentration in the spreadsheet model. All of the variations tried resulted in values much higher than the assigned TMDL load for septic systems in the lower Malibu Creek watershed).

C. Is it possible that seasonal effects are of importance to the average nitrogen load estimation in the Malibu Civic Center area?

Since most homes in the Malibu Civic Center area are owner occupied, little seasonal variation is expected on the wastewater flows from the single homes. Monitoring data large multi-family residences located in the area do not display seasonal significant variation. Wastewater flows from commercial sources do change by season as a function of the number of visitors. Staff observed slightly higher TN loads in the prime summer tourist season. Because the flow rate data in Tables 1 and 3 of Tech Memo #4 are annual averages over several years, seasonal variations were minimized.

D. Staff's judgment regarding the fate of nitrogen during on-site treatment and subsequent transport seems arbitrary. The discussion makes no distinction between ammonium ion absorption, which is both efficient and fast on soil particles, and *nitrification/de-nitrification reactions, which can lower the concentrations of available nitrogen forms and dramatically affect nitrogen transport in the subsurface.*

Because of variations of local site conditions, it is impractical to distinguish the form of nitrogen transport for all wastewater sources in the area. However, as detailed in Tech Memo #2, there are indications showing that natural attenuation (treatment of pollutants in soil) is not occurring in many areas of the Malibu Valley and the nearby Winter Canyon. There are numerous indications that the high density of subsurface wastewater discharges in the Malibu Civic Center Area has exceeded the natural assimilation capacity of the soil profiles. Because the goal of Tech Memo #4 is to determine the long term total nitrogen load of the Malibu Civic Center area to the Malibu Lagoon, the form of nitrogen transport should have little effect to the conclusion of the study. Both the numeric and spreadsheet models assume that total nitrogen is converted to nitrate after reaching surface waters.

E. Staff might comment on the form in which nitrogen is present in the Malibu Lagoon since this bears on the forms in which nitrogen is transferred from on-site disposal locations.

Malibu Lagoon is a unique aquatic system which opens to ocean during raining season and close during dry season. During dry seasons that nitrogen can be accumulated, significant breakthrough of nitrate or ammonia was not observed in the lagoon, but serious eutrophication has been observed. Staff assumes that total nitrogen in groundwater converts in the Lagoon to nitrate.

F. There are some inconsistencies between Tables 1 and 3. Since all the designed parameters are the same for all models, the calculated total nitrogen loads should be the same.

The inconsistencies between Tables 1 and 3 in Tech Memo #4 have been verified and corrected.

G. The non-point source nitrogen contributions to the Lagoon did not appear to have been considered. If these are available from the TMDL calculation, they should be considered as part of the total load.

The total load allocation of nitrogen in the Lagoon is 27 lbs/day. Because non-point sources have already been considered in the TMDL for Malibu Lagoon, they are not included in Tech Memo #4, which is to determine whether the total nitrogen load from OWDSs in the Malibu Civic Center area exceeds the 6 lbs/day allocation required in the TMDL for OWDSs sources. Details of total nitrogen load allocations from non-point sources in the larger Malibu Creek watershed are detailed in the TMDL (USEPA, 2003) and available on the Regional Board website at http:www.waterboards.ca.gov/losangeles.

H. How much a 6 lbs/day of nitrogen addition to the lagoon is likely to increase the available nitrogen levels in Malibu Lagoon?

An evaluation of nitrogen mass loading in Malibu Lagoon is given in Attachment 4-1 (by Dr. Lai) of Tech Memo #4. Figure 5 of Attachment 4-1 indicates that, assuming no other sources exist, a 6 lbs/day of total nitrogen load into the lagoon would bring the nitrogen concentration in the water from 0 to approximately 0.5 mg/L.

Editorial and grammatical suggestions have been followed as appropriate, but are not addressed here. A revised Tech Memo #4 that incorporates changes made in response to peer review comments is posted on the Regional Board website at http:www.waterboards.ca.gov/losangeles.

Staff would like to thank all three peer reviewers for their thoughtful review of Tech Memo #4 and providing their comments in a very timely, professional manner.

State of California
California Regional Water Quality Control Board, Los Angeles Region

Peer Review

Technical Memorandum #4:
Nitrogen Loads from Wastewater Flowing to Malibu Lagoon are a Significant Source of Impairment to Aquatic Life

By

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Memorandum

5 September 2009

To: Ms. Wendy Phillips; Chief, Groundwater Cleanup and Permitting Section, CA Regional Water Quality Control Board

From: Bob Arnold

Subject: Review of Regional Board Staff Technical Memorandum #4. Nitrogen loads from wastewater flowing into Malibu Lagoon.

I will first address the technical issues that were identified for peer review in attachments to your email note dated 28 August. Issues are taken in the order that you suggested.

1. The approach used to inventory wastewater discharges in the Malibu Civic Area (255,000 gallons per day). The flows inventoried fell into the following four classes:

(i) Large, permitted commercial enterprises with Waste Discharge Requirements (WDRs). A subset of these sources provide advanced wastewater treatment (undefined in the report) prior to effluent discharge. The other subset provides only septic treatment prior to discharge. For these sources there is a record of both wastewater volume generated and total nitrogen concentration (Kjeldahl, nitrate, nitrite) discharged to the environment.

(ii) Smaller permitted commercial sources, which also produced a record of wastewater volumes, but were not required to analyze for nitrogen forms in treated effluent. These sources seldom if ever provided advanced treatment prior to discharge.

(iii) Small businesses that were not regulated by the state and for which there was no official record of wastewater volume generated or probable total nitrogen concentration in treated waste.

(iv) Private residences, for which there was no record of wastewater flow or effluent quality.

Thus a complete inventory of the required wastewater volume generated required the authors to find or otherwise estimate the following information, generally from the tertiary sanitary engineering literature and/or the assumptions noted below:

- For dischargers in class (i) the volume flows and nitrogen levels provided all information necessary to calculate flows and respective nitrogen loads at points of discharge.
- For smaller, permitted commercial sources (class (ii), above) flow data were available, but nitrogen levels would depend on an assumption (see below) regarding total nitrogen level.
- Small business flows were estimated using information derived by staff regarding on-site population and business activity. Detailed information/methods for these steps are not described in Technical Memorandum No. 4.

- Flows from residences were estimated based on 100 gallons per day per residence bathroom.

There is very little to criticize in this approach to volume estimation. A few details or perhaps examples of the process by which flows were assigned to small, unpermitted businesses might provide a feel for this work. However, the magnitude of flow generated by this class of dischargers must have been fairly small and probably insignificant ---- making the quality of assumptions used or accuracy of related estimates almost irrelevant within the context of the overall exercise. To make this plain, it would be useful to organize the eventual flow information by class of discharger within each of the geographical sectors within the study area. It also seems possible that water use data, if uniformly available for small businesses could have been used to generate estimates of wastewater flows. It seems very unlikely that such an alternative approach, however, would have led to materially different results at the conclusion of the nitrogen analysis. In a sense, assumptions regarding domestic flows are the most critical, inasmuch as treated domestic wastewater is a major contributor to the eventual calculation of the nitrogen load to Malibu Lagoon. Again, water demand data might have been used to generate wastewater flow estimates.

In general, I am satisfied that no set of alternative (rational) assumptions would have materially improved the quality of the analysis to this point.

2. Methods for calculating nitrogen load contributions from individual OWDSs. Again relying on the four classes of dischargers within the Malibu Civic Area:

(i) Total nitrogen data were available for large, permitted commercial sources with WDRs. Again, there is no clear indication of which specific sources fell within this category in any of the summary tables, so that the efficiency of advanced wastewater treatment processes (unspecified) for nitrogen management cannot be determined from the Table 3 data.

(ii) It was assumed that the smaller, permitted, commercial sources produced an effluent that was similar to domestic effluent quality following septic treatment. The report indicates that some effort was undertaken to express effluent strength, including total nitrogen concentration as a function of the type of business practiced on site. Details and intermediate results from that work are not provided, however.

(iii) Site-specific information was used to anticipate total nitrogen concentration at unpermitted commercial facilities. Again, essentially no information is provided with which to illustrate the type of information collected, methodology for its conversion to nitrogen concentration or nitrogen load, and so forth.

(iv) The total nitrogen concentration in residential wastewater was estimated by assuming that the concentration of total nitrogen (as N) was a constant fraction (0.21) of the five-day biochemical oxygen demand. The correlation was taken from an exceptionally important sanitary engineering text and should be at least approximately correct.

I have the following reservations regarding the approach taken to estimation of nitrogen concentrations for the purpose of nitrogen load allocation at respective discharge points:

- Although the correlation between total nitrogen concentration and BOD_5 (0.21 mg/L as N per mg/L BOD_5 as O_2) may be accurate for domestic wastes, the justification for its use in this context is misleading. The authors contend that nitrogenous oxygen demand is a consistent contributor to BOD_5 (p. T4-4). In fact, the kinetics of biochemical oxygen demand may be dominated by carbonaceous oxygen demand over the first five days of the BOD measurement. This does not invalidate the approach taken, inasmuch as both total nitrogen and BOD_5 are useful indicators of the strength of a waste and are likely correlates in domestic wastewater. Since BOD_5 data were more broadly available than total nitrogen data, the method of estimation probably has merit. For those cases in which both BOD_5 and total nitrogen data are available, however, the authors should provide them --- to demonstrate the strength of the correlation.

- No attempt is made in the report to define "advanced" OWTS treatments. In the interest of defining the most significant sources of nitrogen load, the facilities that provide advanced treatment, the nature of the treatment provided and typical BOD_5 and total nitrogen removal efficiencies might be added to the report.

- The choice of BOD concentrations , absent data, and thus total nitrogen concentrations (21% of BOD_5) seems arbitrary:

Facility Type	BOD_5 (mg/L)	TN (mg/L as N)
Shopping centers with restaurants	800	160*
Small Offices	220	40
Schools		45-75**

* reduced to 80 mg/L to reflect frequent pumping of septic tanks at Malibu Country Mart.

** dependent on soil type and groundwater separation.

Nevertheless, any other assignment of values would be equally arbitrary and probably no more reasonable than the values chosen for the nitrogen loading models. At the end of the exercise, however, it isn't possible to determine which facilities were included in each class (large commercial, small commercial without water quality data, etc.) so it is not possible to reproduce the spreadsheet calculations from the data provided. Given that reviewers will be incapable of performing independent calculations, the authors might carry out their own sensitivity analysis-------to determine which parameters are the primary determinants of the eventual nitrogen load estimates. A good candidate for sensitivity analysis, for example, is the 80 mg/L (as N) total nitrogen concentration that is assumed for some of the commercial sources. Were this value actually 40 mg/L, would the outcome of the analysis change dramatically? The spreadsheet approach is well suited to make such repetitive calculations, and the results could be illuminating. This comment applies to several of the assumed parametric values.

- Various data elements are missing from table 1, page T4-20. Is there a reason for this?

- The apparent importance of residential contributions to regional nitrogen loading suggests that it may be important to distinguish between reported literature values (20, 45, 85 mg/L as N)---to make a selection that is appropriate for Malibu. If local data exist with which to make this distinction, they should be cited in the text. I failed to find data related to nitrogen levels in septic tank effluents, although staff suggested that measurements in septic tank effluent had been made. Absent data, the sensitivity of spreadsheet results to the assumed value should be determined.

- Finally, is it possible that seasonal effects are of importance to average nitrogen load estimation in the study area? No mention was made of variation in population or commercial activity in the Malibu study area. However, since estimated groundwater travel times to Malibu were sometimes on the order of decades, it is conceivable that winter occupancy rates and seasonal commerce might lower annual average nitrogen loading rates in a way that also lowers the average nitrogen load at the Malibu Lagoon. Since neither this study nor previous studies seem to have considered seasonal effects, it seems likely that they are unimportant in this context.

3. Division of the Malibu Civic Center area in hydrologic zones. There is clear justification for division of the study area into hydrologic zones. This seems like a very good way to account for substantial differences in fractional contributions of wastewaters to the Malibu Lagoon that arise from consideration of topography, water table contours and groundwater travel times to the lagoon. The breadth of both fractional contributions and estimates of groundwater travel times is a little unnerving. That is, travel times are held to vary from up to 50 years, for at least a portion of the wastewater discharged in sector I to less than one year for a portion of the flow that originates in sector II. The estimated fractions of discharged wastewater that reach the Malibu Lagoon range from 1% (Winter Canyon, main area sector IV, Sector V) to 95% (sector II much of sector III). The approach is sound, in my opinion, and potentially allows planners and engineers to discriminate geographically in making decisions regarding the importance of new sewerage to the quality of water in the Malibu Lagoon. That is, based on nitrogen considerations alone, it seems probable that new construction would be best deployed in sectors II, III and part of IV. The effects of that construction on lagoon water quality should be relatively rapid due to the short, estimated travel times. The staff's own spreadsheet model can be used to estimate fractional reductions in annual nitrogen load to Malibu Lagoon as consequence of several possible sewerage configurations. Staged construction and water quality response in the lagoon could then be used to avoid unnecessary extension of the sewage system.

I offer just a few comments in this area--- use of hydrological sectors, etc:

- Since water table contours are not provided in the report, readers are obliged to accept staff's opinion on gradients and groundwater flow directions. A contour map would undoubtedly lead those reviewing the document to the same conclusion that was reached by staff and would better ground the very significant assumptions about flow routing and contribution to Malibu Lagoon that are presented in the document. Such a contour map should be developed and included in the report if it is practical to do so.

- Where the selection of flow contribution by sector or sub-sector has an element of uncertainty, staff should examine the sensitivity of their general findings to the fraction adopted. The spreadsheet solution should make such an exercise accessible, and the results would likely show that staff findings are robust with respect to selection of sector-dependent factors governing respective fractions of on-site discharges that reach the lagoon.

- Judgment regarding the fate of nitrogen during on-site treatment and subsequent transport seems arbitrary. While estimated nitrogen losses may have been conservatively high, contributing to the strength of the staff's eventual findings and recommendations, it would be preferable to cite local data for the loss of total nitrogen during on-site treatment, and the discussion of nitrogen fate and transport following discharge is inadequate. That discussion makes no distinction between ammonium ion absorption, which is both efficient and fast on soil particles, and nitrification/de-nitrification reactions, which can lower the concentrations of available nitrogen forms and dramatically affect nitrogen transport in the subsurface. Furthermore, the availability of molecular oxygen in groundwaters affected by on-site discharges deserves attention since oxygen is required for nitrification. Finally, staff might comment on the form in which nitrogen is present in the Malibu Lagoon since this bears on the forms in which nitrogen is transferred from on-site disposal locations.

4. Model adjustment using new nitrogen load factors. I have nothing to say about the use of updated nitrogen load factors to adjust model results. This activity seems well justified and takes advantage of previous modeling work.

5. Other comments. I could make about a dozen grammatical suggestions but have not since this lies outside the scope of my review. I can send a marked up electronic version of the draft technical memorandum if you like.

In the end, I think that none of the comments offered here will materially alter the results of staff's analysis. Sensitivity analysis can be better used to show that analytical results are in fact robust with respect to tributary assumptions. Staff is well positioned to use their spreadsheet model for that purpose.

Although it goes beyond the limits of my review, I would like to know how much 6 lbs/day of nitrogen addition to the lagoon is likely to increase available nitrogen levels in Malibu Lagoon. To that end, what would be the incremental change in total nitrogen concentration in effluent from the Malibu Creek due to 6 lbs/day (as N) of supplemental nitrogen under some sort of critical flow condition?

Staff's analysis suggests that parts of the study area might be excluded from a sewer construction program since their collective on-site discharge contributes little or nothing to nitrogen levels in Malibu Lagoon. Staged construction would allow regulators to determine the effects of sewerage in areas that are the likeliest source of anthropogenic nitrogen in the lagoon, before extending sewer construction into the other geographic sectors of the study area.

In summary, staff's work is very well done. No set of alternative assumptions is likely to affect the general findings of the report. Sensitivity analysis could be used to demonstrate that point.

State of California
California Regional Water Quality Control Board, Los Angeles Region

Peer Review

Technical Memorandum #4:
Nitrogen Loads from Wastewater Flowing to Malibu Lagoon are a Significant Source of Impairment to Aquatic Life

By

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September 10, 2009

California Regional Water Quality Control Board
Attn.: Wendy Phillips
Chief, Groundwater Permitting and Landfills Section
320 W. 4th Street, Suite 200
Los Angeles, CA 90013

Re: Peer Review of Technical Memorandum #4 in support of an amendment to the Water Quality Control Plan for Coastal Watersheds of Los Angeles and Ventura Counties to Prohibit On-Site Subsurface Disposal Systems – Malibu Civic Center Area

Dear Mrs. Phillips,

Please find enclosed my review of the Technical Memorandum #4 “Nitrogen Loads in Wastewaters flowing to Malibu Lagoon Are a Significant Source of Impairment to Aquatic Life” prepared by Toni Calloway, Orlando Gonzalez, and Dr. C.P Lai.

The review is providing responses to questions formulated in Attachment 2.

Please feel free to contact me if you have any further questions.

Thank you very much.

Sincerely,

Professor Jörg Drewes

Scientific Review Report of Technical Memorandum #4

Nitrogen Loads in Wastewaters flowing to Malibu Lagoon Are a Significant Source of Impairment to Aquatic Life

by Toni Calloway, P.G, Orlando Gonzalez, and Dr. C.P Lai, P.E.

a. The approach used to compile an inventory of wastewater discharges from OWDSs in the Malibu Civic Center area, which staff estimates to total 255,000 gallons per day.

Wastewater discharges in the Malibu Civic Center area originate from commercial and residential sources. Flow data for commercial sources were available from monitoring reports for facilities permitted by the Regional Water Quality Control Board. Therefore, the flow estimate for commercial sources can be considered to be fairly accurate.
For residential sources, the number of individual residencies was determined using public records and aerial photographs that were used to confirm the number of residencies. This number can be considered as very accurate. Flow data for residential sources was based on the number of bedrooms and bathrooms at each residence, which served as a surrogate for the number of persons living at a given residence. A per capita water consumption of 100 gal/day was assumed referencing Table 2-9 (Metcalf and Eddy 1991). This table provides a range of "typical" water consumptions for individual residencies ranging from 40 to 90 gal/day and person (Metcalf & Eddy 1991). The latest edition of Metcalf and Eddy (2003) suggests a typical per capita water consumption of 74 gal/capita day without water conservation and 51.9 gal/capita day with water conservation. A study conducted by the Awwa Research Foundation on 1,100 households determined a per capita water consumption of 60.5 gpcd (Mayer et al. 1999). These more recent numbers would suggest that the assumption of 100 gal/capita day is too high and considering the national average should be corrected to 60-70 gal/capita day. Assuming 70 gal/capita day would reduce the total residential flow to 88,410 gpd and the total flow to 216,879 gpd.

Mayer, P.W., W.B. DeOreo, E.M. Optiz, J.C. Kiefer, W.Y. Davis, B. Dziegielewski, and J.O. Nelson (1999). *Residential End Uses of Water*, American Water Works Association Research Foundation, Denver, CO, 310 p.

b. The methodology used to calculate loads of nitrogen from wastewaters discharged from OWDSs in the Malibu Civic Center area; specifically, staff's interpretation of published literature and assumptions used to calculate nitrogen loads released from OWDSs for those discharges where real data were not available.

<u>General:</u>
- Using BOD concentrations to estimate total nitrogen concentrations when total nitrogen data is unavailable is in principal a reasonable approach. Where neither end-of-pipe nor septic tank effluent analyses were available, staff based the estimation of total nitrogen on typical total nitrogen concentrations reported in the published literature on domestic wastewater composition. In section i) (Commercial Wastewater), the authors refer to two key sources

(Crites and Tchobanoglous 1998 and Metcalf and Eddy 1991) that have been considered regarding ranges of concentrations in typical untreated domestic wastewater. The authors proposed a TN/BOD ratio of 0.2.

The reviewer notes that these particular sources did not distinguish between water characteristics of single sources and raw sewage collected in a centralized sewer system. The wastewater discharged in the Malibu Civic Center area originates from single sources, which have a different make-up regarding organic matter and nitrogen than raw sewage collected in a centralized system. Thus, more appropriate references should be considered to provide a more accurate representation of single source waste streams. A very useful reference that the authors might want to consider is a recent research report published by the Water Environment Research Foundation (*Lowe, K., et al. 2007, Influent Constituent Characteristics of the Modern Waste Stream from Single Sources: Literature Review. Water Environment Research Foundation (WERF), Alexandria, VA*). Based on a comprehensive literature review of waste streams from single sources, findings of this report suggest the following median concentration for septic tank effluents:

Source	BOD (mg/L)	TN (mg/L N)	TN/BOD ratio
Single source	156	55.4	0.36
Multiple sources	184	46	0.25
Food	561	86.5	0.15
Non-medical	244	84	0.344

These results would suggest that a TN/BOD ratio of 0.3 might be more appropriate for single domestic as well as commercial sources (non-medical) than the ratio of 0.2 considered by the authors.

In addition, the authors considered “typical untreated domestic wastewater”. Since in this case, septic tank effluents contribute to groundwater contamination, a water quality leaving the tank rather entering a tank should be considered. While septic tanks achieve little to none nitrogen removal, the EPA Onsite Wastewater Treatment Manual (2002) reports 30 to 50 percent of BOD is removed whereas Lowe et al. (2007) reported 55 percent removal during septic tank treatment. In both cases, BOD changes occurring during septic tank treatment will result in shifting the TN/BOD ratio to higher numbers.

Since this ratio was used in the nitrogen load spreadsheet, that was not available to the reviewer, in cases where no “end-of-pipe” total nitrogen concentrations were available, which percentage was also not available, the reviewer cannot assess whether changing the TN/BOD ratio from 0.2 to 0.3 would have a significant effect.

- p. T4-5, third paragraph. “For commercial dischargers such as small offices where we have no data, we choose a low BOD of 220 mg/L, and estimated the TN to be 40 mg/L.”

What is the basis for this estimation? As mentioned above, the authors might want to consider findings reported in Lowe et al. (2007). Findings reported in this study would suggest that the BOD concentration for “small offices” is matching the median concentration of 244 mg/L for non-medical sources, but the total nitrogen concentration is only 50 percent of what was determined for non-medical sources (i.e., 84 mg/L N). Thus, the release of nitrogen from these sources is potentially significantly underestimated.

- p. T4-5, fourth paragraph, last sentence. What is the basis (reference?) for reducing estimated total nitrogen concentrations depending on soil profile and groundwater separation? Why is credit given to subsurface treatment where no credit is given to BOD during septic tank treatment?

- The estimation of the total commercial flow seems reasonable and supported by actual flow data.

- In section ii) (Residential Wastewater), the underlying assumption to estimate the residential flow is 100 gal/capita day. Please see discussion under a.), but the water consumption based on more recent studies would suggest 60-70 gal/capita day.
The estimation of nitrogen concentrations in domestic wastewater is referencing Metcalf and Eddy (1991) with three values (20, 40 and 85 mg/L) for weak, medium and strong wastewater. In the most recent edition of Metcalf and Eddy (2003) these values were revised to 20, 40 and 70 mg/L N.
The recent study by Lowe et al. (2007) reported a median total nitrogen concentration for residential single sources of 63 mg/L N for raw sewage and 55.4 mg/L N for septic effluent, respectively. These values provide support for the total nitrogen concentration of 60 mg/L for septic tank influent proposed by the Regional Board staff in this memorandum.
Although the staff acknowledged that septic tank systems are limited in their ability to remove nitrogen, which is supported by multiple studies (EPA 2002, Lowe et al. 2007), credit was given to OWDS treatment and the estimated total nitrogen concentration of septic tank effluents in the Malibu Civic Center area was reduced from 60 to 45 mg/L N. The basis for this reduction is weak at best.

- Summary of Total Nitrogen Loading from Commercial and Residential Sites
The estimation of total nitrogen releases from commercial sources could be affected by the used TN/BOD ratio of 0.2, which was suggested to be closer to 0.3. For the residential sources, considering a 70 gal/capita day water consumption and nitrogen concentration of 45 mg/L N, the nitrogen load would have been reduced to 12,118 lbs/year or 33.2 lbs/day. Considering the lower water consumption (70 gpcd) and 60 mg/L N, would reduce the total nitrogen loading from 17,311 lbs/year as stated in the report to 16,157 lbs/year or 44.3 lbs/day. This number is close to the estimate of 47.4 lbs/day provided by the Regional Board staff.

<u>Specifics:</u>
- p. T4-4, first subheading. BOD is defined as “biochemical oxygen demand”, not “biological oxygen demand” as stated. Please revise.

- p. T4-5, first paragraph. “…TN/BOD ratio found in the above popular wastewater textbooks.” The term “popular” doesn’t buy credibility and I’d suggest “peer-reviewed”, which represents a

better term. Regardless, the author might want to consider other references (see discussion above) that might be more suitable.
- p. T4-6, last paragraph, third sentence. “Using reported or estimated using wastewater…”. Typo, deleted “using”.

U.S. EPA (2002). *Onsite Wastewater Treatment Systems Manual.* Report No. 625/R-00/008. U.S. Environmental Protection Agency, Cincinnati, OH.

c. Staff’s characterization of groundwater flow regimes in the Malibu Civic Center area into five hydrogeologic sectors, and staff’s application of the nitrogen loads (calculated from #2 above) into a ‘spreadsheet’ model that estimates attenuation of nitrogen loads released from OWDSs and transported to Malibu Lagoon (i.e. to the point of groundwater recharge into the lagoon) for each hydrogeologic sector.

The proposed characterization of groundwater flow regimes into five hydrogeologic sectors seems reasonable and is well supported. The number of residencies/sources in these sectors is well known. The estimated flow of wastewater in each section could potentially be revised considering a lower per capita water consumption (60-70 gpcd) as discussed above. The same holds true for the considered total nitrogen concentrations for individual sources, which could be adjusted from 45 mg/L to 60 mg/L N.
The assumed total nitrogen load reduction factors by “soil treatment” for commercial sites is reasonable. Given that little is known about site specific conditions of residential sites, the assumption that no soil treatment is occurring is appropriate.

d. Staff’s use of the updated nitrogen loads released from OWDSs (calculated from #2 above) to adjust (update) estimates of nitrogen transported to Malibu Lagoon (i.e. to the point of groundwater recharge into the lagoon), using a relationship already established by a groundwater flow and transport model (which is already accepted by stakeholders in the community).

Besides the comments provided above regarding flow estimation and nitrogen loading from both commercial and residential sites, the use of updated nitrogen loads released from OWDSs to adjust estimates of nitrogen transported to Malibu Lagoon seems reasonable. The adjustments made in these calculations are appropriate (concentrations might change and discharge volumes, see comments above). The only aspect that is somewhat inconsistent is the assignment of a “Leach Field Reduction”. What constitutes a reduction of 10 percent vs. 20 percent? In Sector 3, sites with a soil type “sand, silt & clay” and depth to groundwater of 10 or >10 were assigned reduction credits between 0 and 20 percent!?

Overarching questions:

(a) In reading Tech Memos #3 and #4, are there any additional scientific issues, not described above, that are part of the scientific basis of the proposed rule? If so, please comment with respect to the statute language given above.

Regarding Tech Memo #4, there are not additional scientific issues that need to be addressed.

(b) Taking each of Tech Memo #3 and #4 as a whole, is the conclusion of each tech memo based on sound scientific knowledge, methods, and practices?

Regarding Tech Memo #4, with the exception of comments provided above regarding flow estimation and nitrogen loads, the conclusions presented in this Tech Memo are based on sound scientific knowledge, methods, and practices.

State of California
California Regional Water Quality Control Board, Los Angeles Region

Peer Review

Technical Memorandum #4:
Nitrogen Loads from Wastewater Flowing to Malibu Lagoon are a Significant Source of Impairment to Aquatic Life

By

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Peer Review of Technical Memorandum #4: Nitrogen Loads in Wastewaters flowing to Malibu Lagoon Are a Significant Source of Impairment to Aquatic Life, by Tony Calloway, P.G., Orlando Gonzalez, and Dr. C.P. Lai, P.E.

JoAnn Silverstein, Ph.D., P.E.
September 12, 2009

<u>Determination for issues requested in Attachment 2: Description of Scientific Issues to be addressed by Peer Review.</u>

a. Approach used to compile an inventory of wastewater discharges from OWDSs in the Malibu Civic Center area, which staff estimates to total 255,000 gallons per day.

Residential wastewater flow was estimated to be 100 gal/toilet/day, which is assumed to represent the wastewater generated by one person. The 349 residences had 1,263 bathrooms producing the estimate in Table 1 of 126,300 gal/day of residential wastewater. The rationale for the one person per toilet equivalent is not given. However, accepting that equivalent, 100 gallons per capita per day (gpcd) is high for households of more than two persons. A more recent text estimate for domestic wastewater flow rates for households of 3 – 4 persons is 41-71 gpcd (Metcalf and Eddy, 2003). The Onsite Wastewater Treatment Systems Manual (USEPA, 2002) reports estimates of residential wastewater ranged between 50 and 70 gpcd for homes built before 1994. For newer homes with water-saving fixtures, the reported range of wastewater flow rates was 40 – 60 gpcd. The US Census Bureau estimated that the average household size (1998) was 2.7 people per residence. With 349 residences with on-site systems, the population equivalent based on Census data would be 942, and the corresponding wastewater flow rate using the more conservative EPA flow rate range (pre-1994 homes) would be 47,000 to 66,000 gal/day, approximately half or less than the flow rate estimated in Table 1: 126,300 gal/day. Another method to estimate wastewater flow is to use the number of bedrooms, and assume 1 – 1.5 people/bed. Since the number of bathrooms and bedrooms are nearly identical in Malibu, this would produce a population range of 1,263 to 1,894, and a flow rate range, using the EPA per capita flow rate range of 63,000 to 133,000 gpcd. Only the most conservative assumptions of 1.5 persons per bedroom (or bathroom) and 70 gpcd wastewater flow produce flow rate close to the value in Table 1. For one person per bathroom (and bedroom), at the high per capita flow rate, the estimated residential flow is 88,400, 30% lower than the Table 1 value. The high residential wastewater flow rate estimated in Table 1 is not well justified given estimation methods reported in the literature. Consideration should be given to characterizing the uncertainty in the residential wastewater flow estimates, including reporting values with fewer significant figures than 4 – 6 significant figures in Table 1 entries.

For commercial properties, flow data were available for permitted sites that were assumed to be representative of average flow rates. Flow data for unpermitted sites was estimated but the method used was not reported. For example, the basis for 400 gal/day for small commercial facilities should be given. Also, it would be useful to indicate in Table 1 which commercial facilities were unpermitted. In addition, the percent of the commercial flow estimate of 128,469 gal/day that was estimated would provide a better indication of the uncertainty in the commercial flow rate estimates.

b. *The methodology use to calculate loads of nitrogen from wastewaters discharged from OWDS's in the Malibu Civic Center area; specifically staff's interpretation of published literature and assumptions use to calculate nitrogen loads released from OWSDS's for those discharges where real data were not available.*

Residential nitrogen loads were estimated assuming that wastewater discharged from septic tanks contained 45 mg/L total nitrogen. Estimates of residential septic tank effluent (STE) nitrogen concentration range from 40 to 100 mg/L, depending on influent water quality, tank hydraulic and solids residence times (USEPA, 2002). The total nitrogen mass loading from residential on-site systems was estimated to be 47.429 lb/day (too many significant figures!), based on the estimated residential flow rate of 126,300 gal/day and average STE total nitrogen of 45 mg/L. As a check, the estimate of 0.03 lb-TKN/cap/day (Metcalf and Eddy, 2003) and the population estimate based on bathroom number were used to calculate a total nitrogen loading from residences in the study area: to be 38 lb/day. Assuming no attenuation of nitrogen in a septic tank, this is ~19% lower than the estimated daily loading rate from residences of 47 lb/day in Table 1. Most literature reports indicate that almost 90% of the nitrogen in STE is in the form of ammonium. Removal of nitrogen in a subsurface wastewater infiltration system (SWIS) or leach field occurs by a combination of sorption, biomass uptake, and nitrification-denitrification and was estimated in the groundwater loading section of Technical Memorandum #4, as summarized in Table 3.

Eight businesses served by package plants appeared to be the only commercial discharges where effluent total nitrogen data were available. These plants constituted 46% of the estimated commercial flow (59,000 gal/day) but had consistently lower effluent nitrogen than other commercial discharges, constituting 8 lb-TN/day, which was only 19% of the daily total nitrogen load in the study areas (42 lb/day).

Commercial septic tank effluent not reported was estimated, typically as a fraction of BOD, the second of two key assumptions (page T4-5, paragraph 1). (By the way, the callout for Table 2 in this paragraph appears to be wrong. The nitrogen loading spreadsheet is Table 1.) It is widely recognized that some commercial facilities, particularly restaurants, have very high BOD concentrations compared with residential wastewater. However, the 0.18 – 0.21 TN:BOD ratio from the literature which was used to estimate the total nitrogen concentration in commercial wastewater effluent was based on residential wastewater characterization, where as much as 78% of the nitrogen comes from toilet waste (urea) (USEPA, 2003, Table 3.8). In restaurants, the excess BOD probably comes from food waste, oil, and grease, which should have a generally lower TN:BOD ratio. One study (Converse et al, 1984) found restaurant that septic tank effluent total nitrogen ranged from 30 to 82, with a flow-weighted mean of 57 mg/L and an average TN:BOD ratio of 15.6 g-N/g-BOD_5. This is a concern in the reliability of the commercial wastewater nitrogen loading estimate. Nine commercial discharges had estimated nitrogen concentrations $\geq$ 75 mg/L and were 27% of the commercial wastewater flow. Together the nitrogen discharged from them was 9,000 lb-TN/year, which was 58% of the total commercial nitrogen loading estimate. The effluent nitrogen concentration in just one of these, (Malibu Inn and Restaurant) was estimated to be 110 mg/L at a flow rate of 6,200 gal/day, which means that the discharge from this one facility constituted over 13% of the total commercial nitrogen load. Given the impact of the commercial discharges with high nitrogen on the total loading estimate, it is advisable that samples be taken verify the high nitrogen discharge numbers, particularly if the nitrogen concentration estimates were based on the TN:BOD ratio characteristic of residential wastewater. Moreover, characterization of the uncertainty in these estimates, incorporating better values of restaurant wastewater from the literature, and perhaps analysis of the sensitivity of the total nitrogen loading rate to estimated high nitrogen loading rates should be done.

c. *Staff's characterization of groundwater flow regimes in the Malibu Civic Center area into five hydrogeologic sectors, and staff's application of the nitrogen loads (calculated from #2 above [should be b?[) into a spreadsheet model that estimates attenuation of nitrogen loads released from OWDS's and transported to Malibu Lagoon (i.e. to the point of groundwater recharge into the lagoon) for each hydrogeologic sector.*

Division of the region into topographic and hydrogeologic sectors to calculate groundwater flow and associated nitrogen loading rates to the Malibu Lagoon, summarized in Table 3, is a good approach. Estimates of attenuation of nitrogen in SWIS's were very conservative, from 0 to 20%; whereas typical estimates in the literature ranged from 10 – 40% based on soil type. Given that most of the soil in the region was high permeability sand and silt, this may be reasonable. It appeared that the 0% removal was applied when the depth to the ground water table was < 5 ft, regardless of soil characteristics. The other assumption was that nitrate could be used as a surrogate for total nitrogen discharged to the groundwater. This assumes significant nitrification (bacterial oxidation of ammonia to nitrate) in the unsaturated zone, which is supported by the literature. In one case study, the average nitrate concentration in a fine sand SWIS peaked at 21.6 mg/L NO_3-N at a depth of 0.6 m (2 ft), but was still high, 13 mg/L NO_3-N, after percolating to a depth of 1.2 m (4 ft), although there was clearly some attenuation, probably by denitrification, even in the sandy soil (USEPA, 2002). Particularly in wastewater SWIS systems, there will be residual organic matter in the soil that can be used by denitrifying bacteria to reduce nitrate to N_2 gas, so the zero attenuation factor for shallow groundwater table may be too conservative. As with the nitrogen loading estimates, it would be useful to perform a sensitivity analysis for SWIS (leach field) attenuation estimates. Also, if there are monitoring wells near leach fields, nitrate concentrations could be measured to verify these estimates.

d. *Staff's use of the updated nitrogen loads released from OWDS's (calculated from #2 [b?] above) to adjust (update) estimates of nitrogen transported to Malibu Lagoon (i.e. to the point of groundwater recharge into the lagoon), using a relationship already established by a groundwater flow and transport model (which is already accepted by stakeholders in the community).*

The staff's estimate of total nitrogen loading to Malibu Lagoon using the spreadsheet model (Table 4) was 36 lb/day with 38% of the TN mass loading from OWDS reaching the Lagoon, compared with 32% in the numeric model. There is an inconsistency between the spreadsheet column estimate in Table 4 and Table 1 in Attachment 4-1 (page T4-41). In the attachment Table 1, the ratio is given as 40%, with an associated mass loading of 35.7 lb/day. This is a small discrepancy, and may just be rounding difference. However since all the input data are the same, the two tables should be consistent for the spreadsheet estimate. An overall concern is that the rationale for increased commercial loading was not clear, either in section 2.2 of Attachment 4-1 or in Section 3 of the Report (page 4-13-14). Commercial flows increased, but this was captured in the nitrogen loading estimates. The possibility of exceeding soil uptake capacity for nitrogen removal was mentioned in section 2.2 of Attachment 4-1, but there was no indication of how this resulted in an increase in the fraction of the nitrogen reaching Malibu Lagoon from 32 to 38% (or 40% in Attachment Table 1).

The CSTR model used to compare the estimate mass loading to measured nitrogen concentrations was interesting and appears to support the higher estimates of nitrogen loading to the Lagoon. However, the non-point source nitrogen contributions to the Lagoon did not appear to have been factored in. If these are available from the TMDL calculation, they should be considered as part of the total load.

General comments.

Check document for typos, grammatical errors and erroneous callouts. Examples:
p. T4-2, para. 4, line 5: "conservation" should be conservative.
p. T4-3, last line: "facility" should be facilities.
p. T4-5, para 4, line 1 should read: For wastewater generated by commercial facilities…
p T4-6, para 1, line 3 should read: Since 2001, the inventory of commercial properties (delete "on")
p. T4-6, para 5, line 4 should read: Using reported or estimated wastewater (delete second "using")
page T4-7, section Assumptions for Residential Flow and Total Nitrogen Concentration. The estimate of 100 gallons per day per bathroom is for water use, not wastewater generation. You appear to have made the assumption that wastewater generation = water use. This is generally not the case, and Metcalf and Eddy is not correctly cited. (See comments in part a). Also, instead of using the unit 100 gallons per person, the usual unit is gallons per capita per day (gpcd).

Use appropriate significant figures, especially in Tables. Calculated values with 4-6 significant figures do not reflect the input information.

Overarching questions

(a) The scientific basis for the proposed rule, regarding nitrogen discharges from OWDS's to Malibu Lagoon includes estimates not based on site data but literature values, some of which can be questioned (see specific comments in parts a, b, and c above). Overall, a higher scientific standard would be achieved by better characterization of the uncertainty in the estimates, careful use the most recent literature, and analysis of the sensitivity of the results to variation of key input parameters such as flow rates, effluent nitrogen concentrations from OWDS's, and soil attenuation factors.
(b) Even with the concerns above, the general approach and methods used in Technical Memorandum #4 incorporate sound scientific and engineering principles. Adjustments based on less conservative assumptions could lower the OWDS nitrogen loading rate, even by as much as one-third. However, even the lowered loading rate would still far exceed the TMDL, and the conclusion in the Memorandum that the 6 lb/day maximum loading rate for wastewater nitrogen will not being achieved using OWDS's is reasonable and justified.

References

Converse, J.C., R.L. Siegrist, and D.L. Anderson, Onsite Treatment and Disposal of Restaurant Wastewater, Report 10.13, Small Scale Waste Management Project, Univ. Wisconsin, 1984.

Metcalf and Eddy, Wastewater Engineering Treatment and Reuse, 4th Ed., McGraw-Hill, NY. 2003.

USEPA, National Risk Management Research Laboratory, Onsite Wastewater Treatment Systems Manual, EPA/625/R-00/008, Washington, DC. 2002.